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PHYSICS.—*A furnace temperature regulator.*[1] HOWARD S. ROBERTS, Geophysical Laboratory, Carnegie Institution of Washington. (Communicated by Arthur L. Day.)

In 1919 White and Adams described a temperature regulator for direct current resistance furnaces[2] in which the heating coil of the furnace was placed in one arm of a Wheatstone bridge and the heating current was varied by a motor-driven switch controlled by the galvanometer of the bridge. The switch opened or closed the circuit through a shunt around a fixed resistance in series with the furnace but outside the bridge. This arrangement causes the temperature of the source of heat (the platinum wire) to oscillate within rather narrow limits at such a rate that the oscillations in the temperature of a body within the furnace are imperceptible.

Regulators of the Wheatstone bridge type are particularly adapted to long narrow furnaces where the heating element covers nearly all of the surface of the cavity; their use obviates the need for placing any part of the regulator within the furnace, and there is no thermal lag whatever between heater and regulator as there is where the regulator employs a thermocouple placed inside the furnace.

The apparatus set up by White and Adams included a specially constructed galvanometer-relay, and it was with the primary idea of replacing the latter with stock apparatus that the present regulator was devised. Incidentally, the choice of a different type of galvanometer has overcome one rather serious defect in their apparatus.

DESCRIPTION OF THE REGULATOR

Figure 1 is a schematic diagram of the present regulator. It is intended for use with furnaces whose resistance when hot lies between 2.5 and 10 ohms, requiring not more than 15 amperes at 110 volts direct current. For heavier currents a different form of main relay is necessary.

[1] Received September 23, 1921.
[2] Phys. Rev. **14**: 44–48. 1919.

The galvanometer A is essentially a millivoltmeter having a short contact arm or boom in place of the usual pointer, and two contact stops. It differs from the White-Adams instrument in that contact is made as soon as the boom reaches one or the other stop. B is an ordinary polarized telegraph relay, and C a "main line" telegraph relay. The main relay C is operated by current taken directly from the line through the resistance coils R_1 and R_2. It opens when its coil

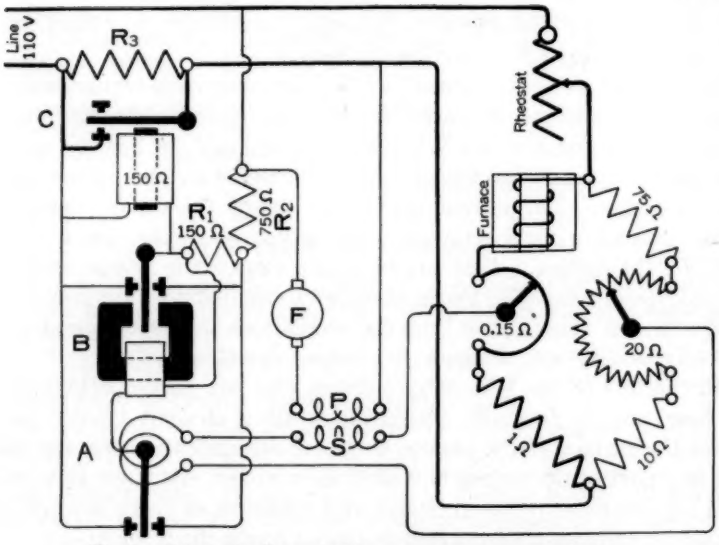

Fig. 1.—Schematic diagram of furnace temperature regulator.

is short-circuited by the contacts of the polarized relay B. The galvanometer contacts are so connected that the movements of the galvanometer place the polarized relay B either in parallel with the main relay C or in parallel with 150-ohm resistance R_1. The operation of the polarized relay, however, immediately short-circuits the particular coil with which it has just been connected, thus stopping the flow of current through the contacts of the galvanometer.

This arrangement was intended to prevent these contacts from becoming welded together, but was found to be insufficient. Therefore, the secondary (low-voltage winding) S of a "bell-ringing" transformer was connected in series with the galvanometer, and the

primary P connected through a "thermal lamp flasher" F to the battery corners of the bridge. The operation of the main relay C increases or decreases the current through P and induces a momentary surge of current through the coil of the galvanometer. The current is caused to pass through the primary P in such a direction that this surge causes a rather violent deflection of the boom away from the contact stop.

The "lamp flasher" F also causes sudden changes in the current through P and corresponding deflections of the galvanometer, which occur independently of the movement of the relay. The violence of the deflection serves to make contact when the contacts have been brought together but have been prevented from touching by a chance accumulation of dirt.

CYCLE OF OPERATION OF THE RELAYS

In describing the various operations of the relays by which the regulator controls the temperature of the furnace we shall arbitrarily assume that a rise in the temperature of the furnace causes a movement of the boom of the galvanometer A toward the left; and that closing the galvanometer contacts to the left sends a current through the polarized relay B in such a direction as to cause its boom to move over to the left-hand contact.

At a given instant, let us say, the contacts of the polarized relay B are closed on the left; the main relay C is then short-circuited and open; the current to the furnace is passing through the resistance R_3, being cut down thereby to its lower value, and the furnace is therefore cooling.

As it cools, the boom of the galvanometer A moves toward the right, and when it touches the right-hand contact, completes a circuit through the coils of the polarized relay B in parallel with the resistance R_1. This causes the armature of the polarized relay to start to move over towards its right-hand contact. The main relay C is now no longer short-circuited, and closes, cutting out the resistance R_3.

When the armature of the polarized relay reaches the right-hand contact it short-circuits R_1 and thus stops the flow of current through its own coils and through the right-hand contacts of the galvanometer A. Since it is a polarized relay, its armature does not swing away from the contact, but remains pressed against it because of the action of the permanent magnetic field of the relay.

With the resistance R_3 cut out, the temperature of the furnace rises and the boom of the galvanometer swings toward the left. When it reaches the left-hand contact it completes a circuit through the polarized relay in parallel with the coils of the main relay C, and the armature of the polarized relay moves over to the left hand contact. This short circuits the coils of the main relay C, whose armature drops back and restores the resistance R_3 to the furnace circuit. The action of the polarized relay B in short-circuiting the main relay C stops the flow of current through its own coils and through the left-hand contact of the galvanometer.

The furnace is now cooling, the relays are in their original positions, and the apparatus continues to pass through repetitions of the same cycle which differ only in the time element.

DESCRIPTION OF THE RELAYS, ETC.

The galvanometer A, in this particular apparatus, was obtained from the Weston Electrical Instrument Company; it has an internal resistance of about 50 ohms and a period of about $^2/_3$ second, and is provided with two fixed contacts and one movable contact, said to be of "iridium alloy." I have separated these contacts to allow room for the ballistic swing, caused by the bell transformer, so that they close at about plus and minus five millivolts. Experience has indicated that the instrument might better have a resistance as low as 10 ohms and a somewhat shorter period even if the sensibility were halved by the change. The contact buttons need to be cleaned about once a day, and polished with fine emery cloth, or a carborundum stone, about once a month.

The polarized relay B of the ordinary telegraph or burglar alarm type is also provided with two fixed contacts. The coils are wound with Number 40 B. & S. gage (0.08 mm.) copper wire to a resistance of 2000 ohms in order to reduce the current through the galvanometer contacts.

The main relay C is of the ordinary telegraph type, wound to a resistance of 150 ohms. It was found well worth while to replace the original silver contacts of this relay, as well as those of the polarized relay, with molybdenum.

The bell transformer is of the size designed to operate an electric bell from a 110-volt lighting circuit.

The "thermal lamp flasher" is a device which depends for its operation on the thermal expansion and contraction of a strip of metal

wound with a heating coil connected in series with the lamp. A suitable contact is arranged to short-circuit the heating coil when the strip has expanded to a certain point, whereupon the strip cools and the contact opens. This particular model is mounted in a tube provided with a lamp base at one end and a lamp socket at the other. For the present purpose, a 60-watt, 110-volt lamp flasher, with a lamp in it, is placed in parallel with another lamp. The effect on the galvanometer may be adjusted by changing from one size lamp to another. A satisfactory combination of lamps in the present apparatus is one which causes the flasher to complete about four cycles per minute.

A satisfactory value for the resistance R_3 is about $^1/_3$ the resistance of the furnace. The rest of the apparatus consists of switches and resistance coils and need not be described. However, it may be pertinent to point out that the resistance wire used in the bridge should be of constantan, advance, ideal, manganin, therlo or some other alloy having a very low temperature coefficient of resistance; that the resistance coils should have ample current-carrying capacity; and that where copper connectors are used in the bridge, these should be short and of large cross section.

PRINCIPLES AFFECTING THE CHOICE OF A GALVANOMETER

This discussion applies particularly to resistance furnaces having a wire resistor wound on an insulating tube and imbedded in a thin layer of insulating cement, both tube and cement, as well as the wire, being good conductors of heat. The heating element as a whole is surrounded by a thick layer of loose magnesia or other nonconductor of heat. With this type of construction, the difference between the average temperature of the wire and that of the tube amounts at high temperatures to several degrees and adjusts itself much more quickly to changes in the heating current than does the temperature of the tube. Consequently, if the heating current is alternately increased and decreased at short intervals the temperature of the heating wire will oscillate through a considerable interval,[3] while that of the tube remains nearly constant.

The average temperature of a point within the furnace depends, among other things, upon the average rate at which energy is supplied to the furnace. Since the regulator must choose between two rates over whose value it has no control, it can only obtain the de-

[3] In the only case studied this interval amounted to at least 2° C. with a half period of about one second.

sired average value by adjusting the ratio of the length of time the one rate is being supplied to the length of time the other is being supplied. In the case of a galvanometer having mechanically operated contacts, the circuit may only be closed at particular instants separated by arbitrarily fixed time intervals. Consequently, the ratio referred to must be approximated by a fraction whose numerator and

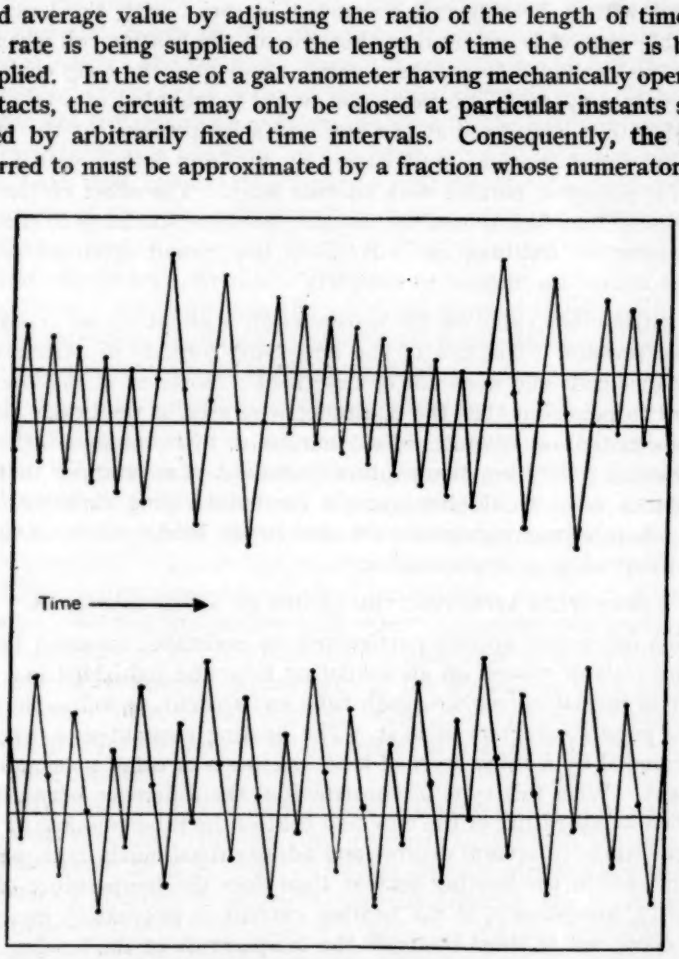

Fig. 2. Diagram to illustrate the periodic fluctuations in temperature of a furnace controlled by a galvanometer having mechanically operated contacts.

denominator are integers. This may consume a considerable number of time intervals and allow considerable fluctuation in the temperature of the furnace tube.

An attempt has been made to show this graphically in figure 2. The wavy line represents the excursions of an idealized galvanometer

boom, while the strip between the parallel lines represents the zone in which the boom may lie without causing a movement of the switch. The black dots indicate the positions of the boom at the instants when the mechanically operated contact mechanism is depressed. The ratio of heating time to cooling time in the upper diagram is 13:12 and there is a slow, cyclic variation in temperature extending over 25 of the equal time intervals. In the lower diagram, where the ratio is 19:31, this slow variation is much less serious. Decreasing the time interval between the successive instants at which contact can be made would undoubtedly improve matters greatly, even if the period of the galvanometer could not be decreased.[4]

The galvanometer with fixed contacts, as used in the present apparatus, is free from this restriction and may make contact at any time. Neither type of galvanometer follows the temperature of the heater very closely; the inertia of the moving coil causes a considerable lag which, however, seems to do no harm.

The regulator has thus far been used only on direct current furnished by a battery or generator. The pulsating direct current furnished by a mercury arc rectifier causes the galvanometer to vibrate seriously because of the alternating current induced in the bell transformer by the pulsations. Several plans have suggested themselves to make it operate on alternating current: partially rectifying the current with an aluminum cell; putting a 6-volt storage battery in series with the source of supply; or making an alternating-current galvanometer. In any case, it would be necessary to operate the bell transformer from a separate source of direct current, or to adopt some other scheme, such as rotating the galvanometer contacts, in order to prevent their sticking. The alternating-current galvanometer has seemed most hopeful and one is now under construction.

Although the foregoing discussion has confined itself to discussing the regulator in combination with a particular type of furnace, there is nothing to prevent the same principles from being applied to other purposes, such as baths of oil or molten metal, or even gas fired furnaces, since it is not necessary to use any part of the bridge as a heater.

PERFORMANCE

When it is used with platinum resistance furnaces at temperatures below 1250° C., this regulator has been found to maintain the

[4] A recent experiment indicates that this interval may be decreased to 1/8 second by a suitable design.

temperature constant within ± 0.1° C. for hours without any attention. At higher temperatures the furnace cools slowly, 2 or 3° per hour at 1450°. This cooling, which is perfectly regular, is undoubtedly due to slow changes in the furnace for the resistance of the heating coil is held constant by the regulator. The cooling can be compensated for by an occasional manual adjustment of the slide wire contact on the bridge.

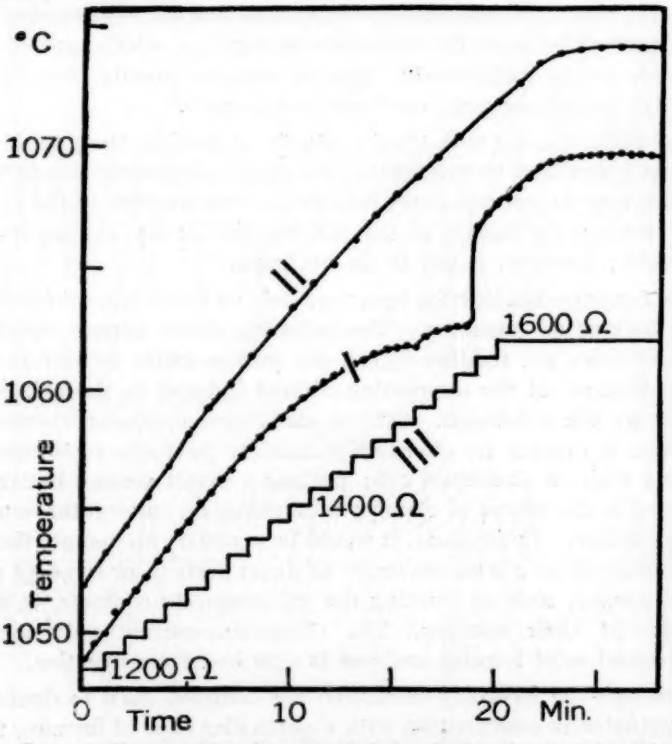

Fig. 3. Curves to illustrate the performance of the regulator in the steady heating of the furnace to determine a melting point.

In a particular experiment, a platinum wound furnace of the type described was being maintained by the regulator at 1269°. Its resistance at this temperature was 9.9 ohms. The galvanometer contacts were set to close at ± 5 millivolts, corresponding to a change of about ± 1° in the temperature of the heating wire. With the rheostat adjusted so that the times of heating and cooling were approximately equal, and the current 10.0 and 7.3 amperes respectively,

the relays operated 59 times per minute. When one ohm more resistance was put in, causing the current to fall to 9.3 and 6.9 amperes, the relays operated 38 times per minute, and the temperature within the furnace fell only 0.1°. This change in the heating current corresponded to a fall of about 6 per cent in the line voltage, about as large a fluctuation as is likely to occur in the voltage of a lighting circuit.

ATTACHMENT FOR STEADY HEATING OR COOLING

If the furnace is to be used in making heating or cooling curves, the adjustment of the regulator must be changed either continuously or by small, frequent steps. The slide wire of the Wheatstone bridge may be used for this, but it has been found more convenient to shunt the 75 ohm coil of the bridge with a rheostat giving steps of 10 ohms from 1000 to 2000 ohms, placed beside the potentiometer used for measuring the furnace temperature. A 10 ohm slide wire rheostat is included in the circuit and used as an alternate fine adjustment for work at constant temperature.

Figure 3 is the heating curve obtained from the melting of a small sample of gold in calibrating a thermocouple. Curve I is the temperature of the gold; II, that of a thermocouple placed a little above it; and III, the resistance in parallel with the 70 ohm coil of the bridge. The heating curve, II, of the furnace is not linear, but it is smooth, and the curve, I, furnished by the sample of gold is entirely satisfactory.

A linear heating or cooling rate can be obtained by means of a simple potentiometer connected in series with the galvanometer.

TECHNOLOGY.—*Radiators for aircraft engines.*[1] S. R. PARSONS AND D. R. HARPER, 3D, Bureau of Standards.

The technologic paper from which this article is condensed will describe the laboratory investigations relating to aircraft engine radiators which were conducted by the Bureau of Standards during the World War and in the two years immediately succeeding it. Individual reports covering many phases of the subject have been published previously in the technical series of the National Advisory Committee for Aeronautics and in scientific and engineering journals. These reports, however, lack the systematic coordination, uniform terminology, and unified mathematical treatment which should

[1] Condensed from a forthcoming official publication of the Bureau of Standards, U. S. Department of Commerce. Communicated by the authors with the permission of the Director of the Bureau of Standards. Received September 24, 1921.

characterize a handbook on the subject. Moreover the problems which were investigated first because of their greater importance and which were the subjects of the reports published earliest, are for that reason not so well covered as is now possible because the later work threw much additional light upon matters not settled at the time of publication of the early reports. Accordingly, the present paper is much more than a reprint of earlier reports, being a complete revision and recompilation of the material available.

The special investigations reported included development of the methods of measuring air flow in radiator tubes; experiments upon the effect of nature of surface upon air flow and upon heat dissipation from the surface of metal tubes to a high velocity air stream; experiments to ascertain the degree of turbulence in the air tubes of a radiator core; mapping of temperature distribution, axially and transversely, in the air tubes of radiator cores. In addition to recording these special investigations, the paper contains a full description of laboratory methods and instruments for those tests of radiator cores properly made in the laboratory both of physical properties and geometrical characteristics such as size and shape of air tubes and of water tubes.

The work included laboratory measurements of cooling power, head resistance, and geometrical characteristics of over one hundred types of radiator core. These data are tabulated in an appendix and the performance characteristics of 66 types of core are given in graphical form. The general conclusions from these measurements and from the special laboratory experiments mentioned above are incorporated into an exposition of the fundamental relations between the conditions under which a radiator operates, its characteristics of form and construction, and the properties which describe its performance. This portion of the designer's field is by no means the whole, however, and the paper does not treat the important considerations of sturdiness, ease of construction and repair, cost, form of design imposed by the structure of the aircraft, etc.

The heat-dissipating power of a given type of core construction was found to be specified completely when the mass rate of air flow was specified. It makes no difference whether a given mass rate is obtained by high velocity and low density or low velocity and high density, a relation which was studied in some detail because of its significance in respect to behavior of aircraft radiators at high altitudes of flight. The empirical relation

$$H = bM^nT$$

(where H is heat dissipated per unit time per unit frontal area of core, M is mass of air per unit area per unit time through the air tubes of the core, and T is difference between the average temperature of the water in the radiator and the temperature of the air at entrance to the core) was found to hold for all ordinary types of core construction, b and n being constants pertaining to any particular core. The numerical value of n was usually in the neighborhood of 0.8, indicating that the relationship between heat dissipation and air flow through the core of a radiator is not far from the relationship of direct proportionality, although too far to assume such a relation over any considerable range of air flows.

A second equation for computing the cooling power of a core is

$$H = C_pMT\ (1 - e^{-\alpha x_1})$$

where H, M, T have the significance quoted in the preceding paragraph, e is the logarithmic base 2.718, C_p is specific heat of air at constant pressure, x_1 is the depth of the radiator core (dimension parallel to air flow) and α is a constant for a given core and given air flow through it. Since a chosen value for α permits no latitude in air flow, or in changing core construction, the equation in this form is intended primarily for study of the effect upon cooling power of changing the depth of core. Giving due consideration to head resistance as a function of frontal area and depth, the formula permits computation of the optimum depth of radiator for given conditions. For very high speed flight, it is advantageous to use cores much deeper than was the common practice in early days of airplane development, 8 to 10 or 12 inches depth being desirable for some types of the usual quarter inch to half inch air tube core, in unobstructed positions.

The formula just quoted is not entirely empirical in its origin, but has a rational basis. The assumptions underlying it are plausible and it is not surprising to find that in applying it to results of measurements with almost all common types of core these results are represented very well. The parameter α is an abbreviation for pq/MC_p, where M and C_p have their former significance; p is total perimeter of the air tubes in unit frontal area, provided the cooling surface is all direct surface (and an equivalent value for the cases where part is indirect cooling surface); q is the cooling coefficient between the metal and an air stream of velocity corresponding to M, namely, q is heat transferred per unit time per unit area of metal per degree tempera-

ture difference between the metal and air flowing past it. The numerical values of q were found to agree very well with values computed from a formula given by Stanton and Lanchester:

$$q = \frac{C_p R_f}{V}$$

and by Lees

$$R_f = \rho V^2 \left[0.0765 \left(\frac{\mu}{V\rho D}\right)^{0.35} + 0.0009\right]$$

the comparison being made for radiator cores with smooth round and square and hexagonal air tubes, nearly all direct cooling surface. The formulas given were originally stated for long circular cylindrical tubes with smooth walls, C_p being specific heat of air at constant pressure, V the velocity of the air through the tube, ρ its density, and μ its viscosity. R_f is the surface friction, or force per unit surface between the air stream and walls of the tube, and D is tube diameter.

The above formulas may be combined into a single expression (making some reductions not given here in detail), so as to compute heat dissipation of a core from its dimensions, and for simple type regular cellular cores it seems highly probable that results will be reliable within 10 per cent.

$$H = MC_pT\ (1 - e^{-\alpha x_1})$$

$$\alpha x_1 = \frac{x_1}{r}\left[0.0471\left(\frac{a\mu}{rM}\right)^{0.35} + 0.0009\right]$$

H = heat dissipated, units of power per unit frontal area of core,
M = mass of air per unit time per unit frontal area,
C_p = specific heat of air at constant pressure,
T = temperature difference water and air entering core.

Any consistent set of units whatever may be used for the above four quantities, but care must be exercised to avoid any inconsistencies; *i.e.*, the heat units for H and C_p must match, the mass units for M and C_p, the area unit for H and M, etc. The same is true for the following sets of quantities, although the units for these need not be the same as the first set.

x_1 = depth of radiator core, in same units as r,
r = hydraulic radius of air tube (quotient of area by perimeter),
M = mass of air per unit time per unit frontal area,
μ = viscosity of air in a unit consistent with M and r,
a = free area of core; the ratio of the total cross section of the tubes to the frontal area. (Being a ratio it is independent of units.)

The laboratory measurements of heat-dissipating power were made with two sources of heat, steam and hot water. For superheated steam, the effective temperature is computed by weighting properly the heat derived in each stage (loss of superheat, condensation, cooling of water):

$$T_m = \frac{\left(T_c + \frac{S}{2}\right)C_p S + T_c L}{C_p S + L}$$

where T_m is mean effective temperature, T_c is temperature of condensation, S is superheat (in degrees), L is latent heat of condensation and C_p is specific heat of superheated steam. The condensate was usually not cooled significantly below the temperature of condensation and the formula above is in the simplified form resulting from neglecting such cooling. An intercomparison of test data on ten cores, using both superheated steam and hot water as sources of heat for the calorimetric measurements, showed that no appreciable difference existed between the results obtained by the two methods. A series of measurements using water as the source of heat were made with the rate of water flow varying over a wide range. As might be expected, a wide range of variation of heat dissipation occurred with change of rate of water flow when the rates were extremely low, but at the rates of flow common in radiator use, the effect was not significant. It seems safe to assume that heat dissipation for conditions all constant except rate of water flow will attain a value within 5 per cent of the maximum which it will reach with any rate of flow, if the rate be as much as 3 gallons per minute per inch depth of core 1 foot wide. This flow is well within the margin of circulation found in most aircraft cooling systems.

The effectiveness of indirect cooling surface, namely, cooling surface not backed by flowing water, is considered in detail and the mathematical relations are developed which describe its behavior. The effectiveness of indirect surface is defined as the ratio of its heat-dissipating power to that of an equal area of direct cooling surface all at the temperature of the edge of the indirect surface which has contact with the source of heat. For long narrow fins such as the indirect cooling surface found in a square cell or hexagonal cell construction, the effectiveness is

$$E = \frac{\tanh U}{U}$$

where U takes the form

$$U = b\sqrt{\frac{2q}{yk}}$$

b is the width of fin where good thermal contact[2] occurs along one edge of the fin only, and is half the fin width where good thermal contact is made by both parallel edges. The fin thickness is y and the thermal conductivity k, the quantity q being the surface heat dissipation coefficient in units consistent with k and the dimensions b and y. For the combinations of values usually occurring in radiator practice, the effectiveness exceeds 70 per cent and quite commonly averages 85 per cent to 95 per cent. The formula was applied to calculate optimum dimensions for fins under various conditions, the results being tabulated. The equations of thermal conduction are also used to compute a table of temperature drop through water-tube walls of various thickness and materials.

A considerable amount of detail not suited to abstracting is to be found in short notes on such topics as effect of yaw on performance, slipstream mountings, wing radiators, shuttering, radiator requirements at altitude and methods of computing performance at altitude from test data obtained at ground level. A brief treatment is included of the subjects of partially streamlined casings to enclose a radiator, and of nose mounting.

From the point of view of an airplane designer, it is desirable to specify radiator performance in terms of flying speed of the plane. In general this cannot be done directly because too many factors are involved in the relation between flying speed and the air flow through the radiator core. It becomes necessary, therefore, for describing characteristics of the radiator, to adopt air flow through the core as the prime variable, there being no other quantity or entity available for the purpose. The ease or difficulty of applying such a description of performance to plane design rests then with the difficulty in estimating the probable air flow through the core for given flying speed. For a radiator mounted in an unobstructed position the difficulties are inappreciable, the estimation process is replaceable by actual measurement and the results are obtainable with satisfactory accuracy. For a nose mounting, or other obstructed position too many factors enter into the determination of the air flow to make generalizations possible. Consequently, the authors are unable to include in the paper material

[2] Soldered or integral metal. Mere contact, unsoldered, of two pieces of metal is thermally a discontinuity.

of direct application, without any intervening step, for the nose radiator, a mounting which is today probably the most common in American practice. The designer who is interested in such a mounting must first secure a measurement or estimate of the air flow to be expected in the core of his radiator, taking into account the size and shape fuselage, engine, propeller, and all the objects which will determine this air flow, and then with such data in hand he can apply all the results of this paper.

The paper is carried one step beyond expressing radiator performance in terms of air flow through the core, and states the results of the measurement in terms of flying speed for a mounting in an unobstructed position. Comparative performance is stated in terms of figure of merit which is the ratio of the power dissipated as heat to the power required to sustain the weight of the radiator and overcome its head resistance in pushing it through the air. The relative figures of merit of two cores in an unobstructed position do not, of course, furnish an index of value in an obstructed position. The comparative behaviors of various classes of core are discussed in some detail for the unobstructed position and it is shown that for this mounting and high speed of flight, the flat plate core construction has a figure of merit sufficiently above other types to deserve attention. Its chief disadvantage is inherent mechanical weakness, a feature of extreme importance in selecting a design for use, and the data presented should afford the designer definite information regarding the sacrifice in figure of merit which must be balanced against increased sturdiness, when choosing between types of core.

For flying speeds of 60 to 200 miles an hour' it seems certain that an unobstructed radiator plus a streamline nose to the fuselage offers a figure of merit so much above that of a nose radiator installation as to justify considerable effort toward overcoming the structural difficulties attendant upon such a mounting.

The measure ments made on a very wide range of variety of cores indicate that vanes, holes in the air-tube walls, and all devices intended to ncrease turbulence in the air tubes are detrimental to radiators in an unobstructed position, lowering the figure of merit for a given flying speed. The effect is to decrease the air flow more than is compensated by the increased heat-dissipating power at a stated rate of air flow. On the other hand, in obstructed positions, where the air flow is determined more by the radiator surroundings than by its own core construction, the cores with turbulence devices

may be advantageous. For regularly shaped cellular tubes, with straight walls, parallel to the wind, and with no vanes or holes, an empirical formula was developed which was found to express air flow through the core in terms of flying speed, with a surprising degree of accuracy:

$$m = a\left(1 - 10^{\frac{-44r}{x}}\right)$$

where r is hydraulic radius of an air tube (quotient of cross section by perimeter) and x is depth of the core (length of an air tube), both these dimensions being measured in the same unit of length; a (the free area of the core) is the ratio of the total cross sectional area of the air tubes in a given frontal area to that frontal area; m is the air flow constant, the fractional part of the air flow approaching the core which passes through it, hence, unity minus the fractional part deflected around the core. In a wind stream of 5 pounds per second per unit area, a core of unit frontal area which transmitted 3 pounds of air per second and deflected the other 2 around it, would have an air flow constant of 0.60. The presence of headers or water boxes would modify the direct application of the formula to a radiator since the formula is for a core alone, but with the exercise of suitable judgment in making an allowance for water boxes and connection piping, it should be possible, from the geometrical characteristics of a simple core, to compute with a satisfactory degree of accuracy the air flow which would correspond to any stated flying speed with the core in an unobstructed position.

ABSTRACTS

Authors of scientific papers are requested to see that abstracts, preferably prepared and signed by themselves, are forwarded promptly to the editors. The abstracts should conform in length and general style to those appearing in this issue.

GEODESY.—*Radio-compass bearings.* OSCAR S. ADAMS. U. S. Coast and Geodetic Survey Spec. Publ. **75.** (Serial **167.**) Pp. 39. 1921.

The radio-compass is coming into very general use for the determination of the positions of vessels at sea. For this reason, it seemed advisable to investigate the methods of plotting bearings thus obtained, both on the Mercator projection and on the gnomonic projection. In investigating the subject it is sufficiently exact to consider the earth as a sphere. It is further assumed that the path of the wireless wave over the surface of the earth is a great circle, joining the position of the vessel with that of the radio-compass station.

A straight line on a Mercator projection represents a rhumb line and not a great circle. A great circle on this projection is represented by a curve

which is concave towards the equator. If an observed bearing is laid down upon such a projection without correction, the line so determined is a tangent to the great circle curve at its point of origin, because the Mercator projection is conformal. This publication gives a mathematical derivation of the correction that must first be applied before the bearing is plotted on the projection. A practical method is then devised so that the required correction may be determined by means of three graphic charts with as small an amount of effort as possible.

For convenience in application the description of the practical use of the method is given first in the publication and the theoretical discussion is given in the final part of the same for the benefit of those who may be interested in this phase of the matter. A Mercator projection table for the sphere is also included as it is of use in connection with the graphic charts, one of the arguments for the same being obtained from it.

On the gnomonic projection a great circle is represented by a straight line, but the angle at the station is not preserved. It is necessary then for any particular gnomonic chart to have a table computed for each radio-compass station that gives the angles that must be laid off on the projection in order that the straight line may represent the great circle with any given observed bearing upon the earth. In this publication, tables are given for ten radio-compass stations along the eastern coast of North America, based upon the U.S. Hydrographic Office Chart No. 1280. O. S. A.

PHYSICS.—*The annealing of glass.* L. H. ADAMS and E. D. WILLIAMSON. Journ. Franklin Inst. **190:** 597–631, 835–870. 1920. (Geophysical Lab. Papers on Optical Glass, No. 32.)

It is shown that the process of annealing glass can best be carried out if we know for the various glasses and for the various temperatures the rate of release of the internal stresses. The results of such measurements for nine kinds of glass are presented. The release of stress at constant temperature was found to proceed usually according to the equation

$$\frac{1}{F} - \frac{1}{F_o} = A\,t$$

in which F is the stress at any time, t, F_o is the initial stress, and A is a constant for the particular glass at a particular temperature, and is a measure of the rate at which stresses are relieved. The variation of this rate with temperature follows the equation

$$\log A = M_1\theta - M_2$$

in which M_1 and M_2 are constants for a particular glass and θ is the temperature.

At any temperature, a glass requires a certain *annealing-time.* This is arbitrarily defined as the time required to reduce the stress (in optical units) from 50 to 2½ $\mu\mu$ per cm. For convenience of reference, the 150° interval of temperature lying immediately below the temperature at which the annealing time is 2 minutes is called (also quite arbitrarily) the *annealing range.* At temperatures below the annealing range as thus defined, very little permanent stress can be introduced.

Concrete directions are given for annealing optical glass. The procedure to be followed for other kinds of glass, such as plate glass, bottles, chemical glassware, etc., is also indicated. Mathematical analysis of the problem shows

that the best method for annealing requires that the glass be held at constant temperature (below the customary annealing point) for the appropriate time and then cooled at an increasing rate. It is of interest to note that the larger the piece of glass the lower the annealing temperature. Finally, there are presented a number of equations which are convenient for calculating the internal stresses due to heating or cooling solids of various shapes.

While the original object of this investigation was to put on a quantitative basis the operations connected with the annealing of glass, it was found that many of the results have an important bearing on certain problems of geophysics. Thus, for example, the relief of internal stresses in glass probably belongs in the category of elastico-viscous flow and is thus connected with such processes as the tidal deformation of the earth's crust. Moreover, the formulas expressing the relation between temperature-differences and stress distribution are directly applicable to the phenomenon of the "jointing" of rocks. L. H. A. and E. D. W.

GEOLOGY.—*Oil possibilities in and around Baxter Basin, in the Rock Springs uplift, Sweetwater County, Wyoming.* ALFRED REGINALD SCHULTZ. U. S. Geol. Survey Bull. **702**. Pp. 107, pls. 17, figs. 9, inserts 3. 1920.

The data for this report were collected in 1907 and 1908 while the area involved was being mapped for its coal resources, and are now made available to meet the demand for information about oil and gas resources. As a consequence the report lacks the detailed information, especially the structure contour maps, usual in reports on this subject, but makes up for that deficiency by the fullness of the information on larger structural features, stratigraphy, oil shales, oil and gas bearing formations, etc. that is brought together for this and surrounding regions. Drilling for oil and gas was active in the Baxter Basin about 1900 but yielded mainly small amounts of gas. A recent revival of drilling had at the time of the report also struck mainly moderate flows of gas and little oil. Land surveys and geography are briefly discussed, and water supply somewhat more fully. In general water supply is poor except that available from deep artesian sources. Sixteen pages are given to a discussion of stratigraphy with detailed description of the principal exposed units which extend from the Baxter shale near the base of the Montana to the Eocene-Green River formation. Valuable correlation tables bring out the naming and subdivision of the entire section down to the pre-Cambrian at various times in this and adjacent areas. Twelve pages devoted to structure in conjunction with the geological map define the principal lines of folding, faulting, and overthrusting and their relation to the adjacent Uinta Mountains. Fifty-foot structure contours on the Rock Spring anticline are the only ones on the map, and it is only in relation to this structure that the possible localization of oil or gas accumulations is disscused.

A conspicuous feature of the report is the general review of the oil shale situation. In the area under discussion oil shale occurs in two portions of the Green River formation. Very full sections of this formation bring out the position of the oil shales; and the character of the beds, their oil content and so forth is discussed. A brief review with map shows the known reserves of oil shale in Wyoming, Colorado, and Utah. There follow 13 pages of discussion of the beds from the lower Montana to the Cambrian that might be reservoirs or sources of oil. The discussion is based mainly on evidence from adjacent areas and is accompanied by a valuable table showing the beds that yield oil and gas in various surrounding Rocky Mountain fields. The

remaining 21 pages of the bulletin are given to a rather detailed account of previous drilling in or near Baxter Basin, that is, mainly on the Rock Springs dome, with brief discussion of the beds that would probably yield oil and of analyses of oils from nearby fields. The author believes that the Frontier sandstones and the Aspen formation, both of which are at the base of the Upper Cretaceous and which in most of the area would be reached at depths of from 2000 to 4000 feet, will prove to be the principal oil-producing beds.

MARCUS I. GOLDMAN.

GEOLOGY.—*Coal in the middle and eastern parts of San Juan County, New Mexico.* CLYDE M. BAUER and JOHN B. REESIDE, JR., U. S. Geol. Survey Bull. 716-G. Pp. 82, pls. 19. 1921.

This report describes briefly the geography and geology of San Juan County, New Mexico, and in detail the coal deposits of the middle and eastern parts. The geologic section includes 9 formations assigned to the Upper Cretaceous and 4 formations assigned to the Eocene. Coal occurs in 2 Upper Cretaceous formations—the Menefee formation of the Mesaverde group and the Fruitland formation. The coal beds of the Menefee formation are in 2 groups, one in the lower part of the formation and one in the upper part, with a barren interval between. Individual beds are lenticular and very variable in thickness and composition. The coal beds of the Fruitland formation are usually grouped in the lower part of the formation and are more persistent and thicker than those of the older Menefee formation. The number of beds and the quality of the coal decreases from north to south. The coal of both formations is of bituminuous rank in the northern part and of sub-bituminous rank in the southern part of the county. The total quantity of coal is large but under present conditions will be developed for local use only. J. B. R.

GEOLOGY.—*The iron-ore resources of Europe.* MAX ROESLER. U. S. Geol. Survey Bull. 706. Pp. 152. 1921.

This bulletin, which is the outgrowth of a report compiled by the U. S. Geological Survey for use at the Peace Conference, is the result of the study of a wealth of literature by many writers in many languages. The author has attempted to reduce the available information to nearly common scale, and to present briefly the distribution, character, and extent of the deposits in the various countries of Europe. The graphic review of the deposits is preceded by a brief sketch of the nature and geology of iron-ore deposits in general and a few notes on the methods of utilizing the ores. The production and consumption of the principal countries is given. The report contains many maps and diagrams and an extensive bibliography. R. W. STONE.

GEOCHEMISTRY.—*Chemical researches on sediments.* H. E. MERWIN. Bull. Geol. Soc. Amer. 31: 419–424. 1920.

A general discussion of various phases of the chemical problems connected with the study of sedimentary rocks. The problems are difficult because of the complexity of the chemical solutions, the small solubility and lack of definite crystallinity of many of the substances, and the persistence of unstable phases. Diffusion in the solid state, consolidation under differential stress, adsorption, slow reactions, and effects of catalysis are discussed both in general terms and in their relation to the formation of dolomite and phosphate rocks and the oceanic red clay. H. E. M.

GEOCHEMISTRY.—*The chemistry of the Earth's crust.* HENRY S. WASHINGTON. Journ. Franklin Inst. **190**: 757–815. 1920.

The number of essential rock-forming minerals is very small. They are mostly silicates of Al, Fe, Mg, Ca, Na, and K. Any two or more of these minerals (with two exceptions) may occur together and in all proportions. The chemical characters of igneous rocks are summarized in the paper and the ranges and maxima of the various constituents are given. The average igneous rock is considered and, after some discussion of the sources of error involved in the calculation, a new average (based on 5179 analyses) is given. The average rock is shown to be approximately a granodiorite. The average composition of the Earth's crust in terms of elements is also given. Twelve elements (O, Si, Al, Fe, Ca, Na, K, Mg, Ti, H, P, and Mn) make up 99.61 per cent of the crust.

The elements are referred to two main groups in the periodic table: (1) the petrogenic elements, characteristic of and most abundant in igneous rocks, of low atomic weight and occurring normally as oxides, silicates, chlorides, and fluorides; (2) the metallogenic elements, rare or absent in igneous rocks, but occurring as ores, of high atomic weight, and forming in nature metals, sulfides, arsenides, etc., but not oxides or silicates. The suggestion is made that beneath the silicate crust of petrogenic elements is a zone essentially of nickel-iron, and beneath this a central core of the metallogenic elements. This vertical distribution is in accord with Abbot's views as to the distribution of the elements in the Sun.

In igneous rocks and minerals the elements show a correlation, in that certain of them are prone to occur with others, and a similar limited correlation is apparently true of the animal and vegetable kingdom.

The idea of "comagmatic regions," that is, the distribution of igneous rocks in regions of chemically related magmas, is discussed, and some of these are briefly described.

The calculation of rock densities from their chemical composition is discussed, and the average chemical compositions and densities of the continental masses and oceanic floors are given. It is shown by these that the average densities of the continents, ocean floors, and various smaller regions of the earth stand in inverse relation to their elevations. The bearing of this relation of average density and elevation on the theory of isostasy is pointed out, and it is shown that the data presented are confirmative of the theory.

H. S. W.

VOLCANOLOGY.—*Two gas collections from Mauna Loa.* E. S. SHEPHERD. Bull. Hawaiian Volcano Obs. **8**: 65–67. 1920.

Through the courtesy of Dr. T. A. Jaggar, Jr., of the Hawaiian Volcano Observatory, two tubes of gas were received which he collected in November 1919 from the flow on Mauna Loa. These are the first gases collected at this volcano. Dr. Jaggar had great difficulty in finding a suitable source for collecting, and greater difficulty in approaching it. The analysis of the gases accounts for part of the difficulty, since they show 2 and 8 per cent of SO_2 respectively. The combustible gases had practically all disappeared and the samples may be regarded as completely burned. It will be noted, however, that the amount of nitrogen present is not high and could not possibly account for the amounts of water present, namely, 67 and 75 per cent respectively. The argon group is present in rather larger amounts than at Kilauea, but amounts to a maximum of only 0.6 per cent. Free sulfur and chlorine were absent. Compared with similarly oxidized gases from

Kilauea, the Loa gas seems entirely similar in composition. The analyses, in volume per cent at 1200° and 760 mm., are given in the table below.

CO_2	3.84	6.42
CO	0.03	0.19
H_2	...	0.01
SO_2	1.22	1.95
SO_3	2.08	8.12
S_2	...	...
Cl_2	...	...
N_2	16.80	15.39
A	0.58	0.42
H_2O	75.44	67.43

E. S. S.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

GEOLOGICAL SOCIETY

342D MEETING

The 342d meeting of the Geological Society of Washington was held at the Cosmos Club at 8 p.m., on Wednesday, January 28, 1920.

Regular Program

G. R. MANSFIELD: *Types of structure in Southern Idaho.* (Illustrated.)

F. E. MATTHES: *Physiographic history of the Yosemite region.* (Illustrated.)

W. TAYLOR THOM, JR.: *The structure of the so-called Poplar Dome in northeastern Montana.*

343D MEETING

The 343d meeting was held at the Cosmos Club at 8 p.m., February 11, 1920.

Informal Communication

LAURENCE LAFORGE spoke on the correct use in physiography of the terms *mature* and *maturity.*

Regular Program

H. W. CORNELL: *Constitutional questions involved in the statutory classification of mines and minerals for purposes of taxation.*

M. R. CAMPBELL: *Abandoned meanders of James and Potomac Rivers and their bearing on Coastal Plain history.*

SPECIAL MEETING

A joint meeting with the Washington Academy of Sciences was held in the auditorium of the Cosmos Club at 8:15 p.m. on Thursday, February 19, 1920. The occasion was a lecture by ALFRED H. BROOKS on *The application of geology to war.* An abstract of the lecture has been published with the Proceedings of the ACADEMY in this JOURNAL.[1]

344TH MEETING

The 344th meeting was held at the Cosmos Club at 8 p.m., on Wednesday, March 10, 1920.

[1] This JOURNAL, **10**: 331–333. 1920.

Informal Communications

DAVID T. DAY spoke on some substances extracted from oil shale.

R. C. WELLS spoke on a deposit of aragonite on the inside of a sealed glass tube containing a standard sample of sea water. This communication has since been published in the JOURNAL.[2]

Regular Program

F. C. CALKINS: *Thrust faulting in the Cottonwood District, Wasatch Mountains, Utah.*

The thrust faults discovered in the Cottonwood district during 1912 by Loughlin and Butler and independently by Hintze dip in general eastward and hence were naturally supposed at first to have been caused by westward overthrusting. Recent field study, however, has brought out the following facts: (1) The main thrust plane dips westward in part. (2) The eastward dip is in places steeper than it could have been at the time the thrust-faulting occurred, so that some eastward tilting must have taken place; this tilting may well have sufficed to reverse an original low dip to the westward. (3) Most of the drag folds associated with the thrust faults indicate an eastward drag. It is therefore believed that the overthrusting was mainly eastward though a little westward thrusting may have taken place later.

The Cottonwood district lying at the intersection of the Wasatch and Uinta axes and affected by the stresses that caused the birth of both ranges is a favorable place for determining the position of the overthrusting in the history of the region. The order of the early events in that history is believed to be as follows:

At the close of the Mesozoic the site of the Great Basin, instead of being depressed relatively to the region at the east, was largely dry land, and the site of the Wasatch and Uinta Mountains formed part of an area of sedimentation. Deformation of the off-shore sediments began with "Wasatch" folding on north-south axes. This was followed by thrusting of the land mass over the lower basin at the east. Further movement in the same sense caused the thrust faults to be bent into folds whose axial planes lean eastward. The east-west uplift which gave rise to the Uinta Range, and which was accompanied or closely followed by the intrusion of granitoid rocks under the crest of the Uinta arch, was antedated by the overthrusting and probably by most of the north-south folding that affects the thrust planes. The thrust-faulting can therefore hardly be more recent than the end of the Cretaceous

SIDNEY PAIGE: *Interpretation of the Moon craters.*

KIRK BRYAN: *Mountain pediments. A discussion of the erosion of desert ranges.*

345TH MEETING

The 345th meeting was held at the Cosmos Club at 8 p.m., on Wednesday, March 24, 1920.

Informal Communication

Mr. DAVID WHITE exhibited some highly polished chert pebbles found in residual clay of limestone in Missouri.

Regular Program

LEON DOMINIAN: *Geography of Asia Minor.* (Illustrated.)

H. S. WASHINGTON: *The chemistry of the Earth's crust.* (Illustrated.) This paper has been published in full.[3]

[2] R. C. WELLS. This JOURNAL, **10**: 249–254. 1920.

[3] H. S. WASHINGTON. Journ. Franklin Institute, **190**: 757–815. 1920.

346TH MEETING

The 346th meeting was held at the Cosmos Club at 8 p.m., on Wednesday April 14, 1920.

Informal Communication

Dr. G. R. MANSFIELD showed some enlarged photographs of grains of glauconite from the glauconite-bearing deposits of New Jersey, showing the characteristic forms and microstructure of the grains.

Regular Program

J. S. BROWN: *Fault features of the Salton Basin, California.* (Illustrated.)

Salton Basin is in the southeastern corner of California. Its lowest point, now covered by Salton Sea, is 273.5 feet below sea level. The basin is flanked by mountain ranges on the southwest and northeast, but at the southeast it opens toward the Gulf of California, from which it is separated by the delta of Colorado River which is only 50 feet above sea level. The basin floor is a desert plain covered at some places by large sand dunes. At many places the basin is bordered by badlands. The stratigraphy consists essentially of three groups:

(1) Pre-Tertiary crystalline rocks, chiefly Paleozoic and Mesozoic, which underlie the basin and compose the surrounding mountains.

(2) Soft, saliferous sandstone and clay beds of late Tertiary age, usually folded, exposed in the badlands.

(3) Quaternary alluvium, generally undisturbed, forming the basin floor.

Salton Basin is generally conceded to be a graben. Numerous faults have been traced to its borders, the most notable being the San Andreas rift, which extends to the northwestern tip of the basin. Topographic and geologic evidence adduced by the writer indicates the existence of a fault 50 miles long between the Tertiary of the badlands and the pre-Tertiary crystalline rocks northeast of Salton Basin. The name Indio fault is suggested. The Indio fault probably is a continuation of the San Andreas rift. Southwest of Salton Basin two systems of faults are distinguished whose intersections are related to the mountain spurs that project into the basin. These faults have disturbed the pre-existing drainage and created a number of isolated mountain-walled valleys. All the faulting observed is of the normal type. The faulting that shaped the basin began before late Tertiary time, but has progressed more or less continuously to the present day, as evidenced by movement along certain faults in recent earthquakes.

A. E. FATH: *Origin of the faults, anticlines, and buried "Granite Ridge" of the northern part of the Mid-Continent oil and gas field.* (Illustrated.)

J. B. MERTIE, JR.: *The Salt Chuck palladium mine near Kasaan, Alaska.*

347TH MEETING

The 347th meeting was held at the Cosmos Club at 8 p.m., on Wednesday, April 28, 1920.

Regular Program.

DAVID G. THOMPSON: *Pleistocene lakes along Mohave River, California.*

Mohave River is a typical desert river. It rises in the San Bernardino Mountains in southern California, and flows north to Barstow, thence northeastward along the Los Angeles and Salt Lake Railroad. Except in the mountains its channel is dry for many months at a time. Near the station of Baxter the river emerges from a canyon and spreads over a large alluvial fan, distributary channels carrying the flood water to playas in two separate closed basins, where it disappears by evaporation and absorption.

Lake cliffs and terraces and beach ridges show that a perennial lake once occupied the largest basin which is now occupied by two playas called Silver Lake and Soda Lake. The maximum depth of this ancient lake, which may be called Lake Mohave, was about 40 feet and the area about 75 square miles. A small but distinct channel at the north end shows that it overflowed toward Death Valley.

Evidence of another ancient lake, much smaller than Lake Mohave, was found recently in the second basin, which is now occupied by a playa called Cronise Lake. The name Little Mohave Lake is suggested for this lake.

Buwalda has described Manix Lake that existed in the Pleistocene along Mohave River about 25 miles upstream from Little Mohave Lake. No evidence has been obtained as to the relative ages of these lakes. At present the flood run-off of Mohave River from the San Bernardino Mountains is the only important factor in flooding the playas in the Lake Mohave Basin. Under similar conditions in Pleistocene time, if the ancient Mohave River followed approximately its present course, after Manix Lake was formed no great supply of water would have reached the Lake Mohave Basin until Manix Lake overflowed. If, however, Lake Mohave was wholly contemporaneous with Manix Lake, the precipitation in the area directly tributary to the Lake Mohave Basin below Manix Lake must have been considerably greater than it is today. Evidence on the relative age of these lakes will aid in interpreting the climatic conditions under which they existed.

In January, 1916, floods from Mohave River covered Silver Lake playa to a depth of 8 or 10 feet. When the water disappeared 18 months later, many dead fish were found on the playa. These had been carried at least 25 miles from their regular habitat along the river. Fish remains have been reported under similar conditions on the other desert playas. Such occurrences show that fresh-water remains in desert deposits do not necessarily indicate the existence of an ancient perennial fresh-water lake.

The fish belong to two species.—One the common catfish, and the other *Siphateles mohavensis*, which is found only in Mohave River. Other species of the latter genus live in the San Joaquin River, Owens River, Lahontan, and other systems. It is not certain how *Siphateles mohavensis* reached its present habitat, but it is suggested that members of the genus may have migrated from Owens River to Death Valley, through a chain of lakes described by Gale, and thence up the ancient Mohave River, through Lake Mohave. If such a migration took place the same genus ought to be found in Amargosa River which now enters Death Valley.

O. E. MEINZER: *Ground-water problems in the Hawaiian Islands.*

Mr. Meinzer spent February and March, 1920, in the Hawaiian Islands to start a systematic geologic and ground-water survey of the Islands. Work was in progress in 1920 in the Kau district on the Island of Hawaii, by W. O. CLARK and L. F. NOBLE, and in the Honolulu district by H. S. PALMER. The present paper outlined the ground-water problems as seen in this visit of two months.

The rocks of the Hawaiian Islands consist chiefly of small irregular bodies of extrusive lava which is very permeable. This great permeability results in (1) heavy absorption of rain by the rocks, (2) flatness of the water tables, (3) scarcity of springs and streams, (4) large yields of aquifers, and (5) large yields and specific capacities of wells.

The ground water can be divided into two kinds: high-level water and low-level water. The low-level water does not occur much above sea level; the

high-level water may occur hundreds or even thousands of feet above sea level and is held up by definite rock structures such as dikes and interbedded soils and impervious ash.

The high-level water may belong to the main body of ground water or may be a perched body of water not associated with the main body. This water is valuable especially because it does not generally have to be lifted as does the low-level water. The problems of its discovery relate to rock structure and require geologic methods of investigation. The geologic studies should indicate effective but inexpensive methods of prospecting.

The low-level water is in some places non-artesian, but in other places it occurs in artesian basins produced by nearly impervious sedimentary beds overlying the water-bearing lavas. The problems with respect to this water relate chiefly to the quantities available and to contamination by sea water. They require studies of the coasts with respect to emergence and submergence, the consequent development and position of sedimentary deposits, and the effectiveness of these deposits in producing artesian conditions and in protecting the ground water from sea water. They also require quantitative studies of absorption, pumpage, head, and correlative salt content, and studies of the underground leakage of wells and methods for conserving the artesian supply. A valuable contribution to the methods of ground-water investigation developed in the Hawaiian work is the use of current meters for detecting leakage of wells.

Prof. L. C. GRATON spoke on the relation of secondary enrichment to topography and ground water, and especially on the problem of the accumulation of the iron minerals in gossan.

Prof. WM. M. DAVIS was invited by the President to address the Society, and spoke on some reef limestones found in the floors of valleys penetrating the lower slopes of the volcanoes on the Island of Oahu, and their bearing on the diastrophic history of the Hawaiian Islands.

348TH MEETING

The 348th meeting was held at the Cosmos Club at 8 p.m., on Wednesday, May 12, 1920.

Regular Program

Stratigraphy of the Bend Series and contiguous formations in north-central Texas.

P. V. ROUNDY: *Micro-paleontology.*

M. I. GOLDMAN: *Lithology.*

The two papers were discussed by Messrs. GIRTY, WENTWORTH, HEALD, DAVID WHITE, H. BASSLER, STOSE, ALDEN, LOUGHLIN, and G. R. MANSFIELD.

Mr. GOLDMAN'S paper on *Lithology of the "Bend Series" and contiguous formations of north-central Texas* is the result of the study of a nearly complete series of samples (representing mostly intervals of 10 feet) from 2400 to 4510 feet in the Seaman No. 1 well, Roxana Petroleum Corporation, Palo Pinto County, Texas. In each sample as many types of ingredients as could be recognized were differentiated under the hand lens, and their proportions estimated. Peculiar types and at intervals the common types were made into thin sections, studied under the compound microscope, and the proportion of sand, clay, and lime in each type estimated. Three graphic logs were presented; one showing the estimated proportion of sand, clay, lime, sand flint in each sample, another the usual type of graphic log showing the succession of beds as indicated by the above examinations, the third the usual graphic

presentation of the driller's log. From the first-named log (the "percentage log") it appeared that there are in this well distinct lithologic units characterized by the proportion of the four ingredients differentiated, and that the boundaries between these are usually well defined. From the second log it appeared that these boundaries are usually marked by some distinct bed, some times by a conglomerate or sandstone, but in most cases by a coarsely *glauconitic* sandy bed. In this way it was possible to place the boundary between the Marble Falls (Pennsylvanian) and the Lower Bend (Mississippian) with absolute precision and in conformity with the paleontologic evidence. Boundaries between the Marble Falls, Smithwick, and Milsap were also suggested, though in the absence of paleontologic evidence these are uncertain. Other lithologic units not hitherto distinguished by names were indicated. It was shown that the driller's log gives little if any evidence for the most significant criteria.

In further support of a hypothesis previously offered that *unconformities are marked by glauconitic beds* it was shown that a glauconitic layer occurring at the base of the Lower Bend just above the Ellenberger limestone in outcrops in San Saba County had been traced north through all wells (3) examined in which this contact appeared including the Seaman well more than 100 miles north of the outcrop. It was also indicated that pyrite or other sulfides are associated with glauconite and phosphate at unconformities, and it was suggested that the presence of all three minerals is due to the abundance of organic matter encountered by a transgressing sea.

T. WAYLAND VAUGHAN: *Results of recent studies of the geology of the Northern West Indies.* (Illustrated.) (Read by W. P. WOODRING.)

349TH MEETING

The 349th meeting was held at the Cosmos Club at 8 p.m., on Wednesday, November 10, 1920.

Informal Communication

C. K. WENTWORTH: *A sizing scale for the constituents of sedimentary rocks.* (Presented by M. I. GOLDMAN.)

Regular Program

COURTENAY DE KALB: *The Rio Tinto and other historic mines of Spain.* (Illustrated.)

C. W. GILMORE: *Remarks on the reconstruction of extinct reptiles.* (Illustrated.)

LAURENCE LAFORGE, *Secretary.*

350TH MEETING.

The 350th meeting was held in the auditorium of the New National Museum at 8 p.m., on Saturday, November 20, 1920.

Regular Program

WILLIS T. LEE: *An evening "in the air." A popular presentation of the use of aerial photographs in geography.*

Stereopticon views of natural scenery and of objects of geographic interest as seen from an aeroplane were shown, including views of submarine objects and drowned land forms, shown here for the first time. There was also a series of moving pictures taken from hydroplanes, showing scenes along the Potomac, the Pacific fleet passing through the Panama Canal, and scenes along the coast of California. The films were loaned for the evening by the Navy Department.

W. T. THOM, JR., *Secretary.*

351ST MEETING

The 351st meeting was held in the auditorium of the Cosmos Club at 8 p.m., on Monday, December 6, 1920.

Regular Program

O. E. MEINZER: *Recent volcanic events on the Island of Hawaii.* (Illustrated.)

This paper was a concise and graphic presentation of the exceptionally spectacular events in 1919 and 1920 on Kilauea and Mauna Loa—the two active volcanoes of the Hawaiian Islands. It included lantern slides showing one of the lava flows in action, with the two kinds of lava—aa and pahoehoe—being extruded at the same time. The outstanding events of 1919 and 1920, named in chronological order, were (1) long-continued overflow of Halemaumau, the crater of Kilauea; (2) a vigorous lava flow on the flanks of Mauna Loa, nearly 3,000 feet above the level of Halemaumau, this flow reaching the sea, 14 miles from the vent, within 24 hours of the beginning of the eruption; (3) a drop of 600 feet in the lava column in Halemaumau in one night; (4) gradual and quiet opening of fissures radiating from the crater of Kilauea, some of them to a width of 15 feet; (5) gradual rise of lava in some of the fissures and ultimate overflow which developed into a vigorous lava flow with vents about 6 miles from the crater of Kilauea. The specific facts are recorded in the monthly bulletin of the volcano observatory by Prof. T. A. JAGGAR.

The volcanoes of Hawaii have a wide reputation for their gentle habits. When eruptions occur, the inhabitants, instead of fleeing, hastily assemble to see the show. There have, however, been two catastrophes within historic times—an explosive eruption of Kilauea in 1790 which is said to have destroyed an Hawaiian army, and a violent earthquake in 1868 which caused a huge landslide that destroyed many lives. The geological survey of this part of the island begun last year by L. F. NOBLE and the speaker and now being carried out by W. O. CLARK, has, however, revealed numerous beds of volcanic ash and deposits of land-slide material interbedded with lavas at many widely separated horizons, showing that, from the standpoint of geologic time, violent eruptions and huge landslides have not been unusual occurrences.

Baron GERARD DE GEER: *Geochronology and its application to America and to other parts of the Earth.* (Illustrated.)

352D MEETING

The 352d meeting was held in the auditorium of the Cosmos Club at 8 p.m., on Wednesday, December 22, 1920.

Regular Program

BAILEY WILLIS: *Evidences of compression on the Pacific Coast.*

After a brief recess the twenty-eighth annual meeting was called to order. The reports of the Secretaries, Treasurer, and Auditing Committee were read and accepted. The following officers were elected for 1921:

President, G. W. STOSE; *Vice-Presidents*, G. F. LOUGHLIN and F. E. WRIGHT; *Treasurer*, G. R. MANSFIELD; *Secretaries*, W. T. THOM, JR., and LAURENCE LAFORGE; *Members-at-large of the Council*, C. N. FENNER, K. C. HEALD, Miss A. I. JONAS, F. J. KATZ, E. T. WHERRY.

LAURENCE LAFORGE, *Secretary.*

SCIENTIFIC NOTES AND NEWS

The following educational courses are being offered at the Bureau of Standards this winter: C. A. SKINNER, *Advanced optics;* L. H. ADAMS (Geophysical Laboratory, Carnegie Institution of Washington), *Chemical thermodynamics;* CHESTER SNOW, *Interpretation of data, including the theory of errors and methods for numerical, graphical, and mechanical computation;* L. B. TUCKERMAN, *Differential equations.* The committee in charge consists of L. B. TUCKERMAN, *Chairman;* F. B. SILSBEE, *Secretary;* Miss A. K. BENSON, L. J. BRIGGS, L. V. JUDSON, and C. E. WATERS.

Prof. ERNST COHEN, of the University of Utrecht, Holland, and Prof. J. W. MCBAIN, of the University of Bristol, England, visited the scientific institutions of Washington in September.

Mr. WILLIAM H. GAMBLE, topographer and map engraver with the U. S. Geological Survey, and the oldest employee in the Federal service at the time of his retirement in August, died on September 16, 1921, at the age of eighty-five. Mr. Gamble was born in Philadelphia November 4, 1835. He was engaged in map publishing in Philadelphia until 1895, when he joined the U. S. Geological Survey in Washington.

A department of botany has been organized at George Washington University, in charge of Prof. R. F. GRIGGS, formerly of Ohio State University and recently director of the Katmai Expeditions of the National Geographic Society.

Mr. RALPH C. HOLDER has resigned as junior chemist in the food research laboratory, Bureau of Chemistry, to take charge of the chemical laboratory of the Collis Products Company of St. Paul, Minnesota.

Dr. WALTER PROCTOR JENNEY, mining engineer, died at his home at 1417 Park Road on September 16, 1921, in his seventy-third year. Dr. Jenney was born at Fairhaven, Massachusetts, January 11, 1849. He was mining engineer for several railroad and mining companies during the period of development of the mineral resources of the West, and was with the U. S. Geological Survey in the years 1889–1892. In 1909 he became interested in the investigation of ship forms for the Navy Department and was in that work through the War period. Since 1919 he had been engaged in research work for the Department of Agriculture.

Mr. HUGH MILLER, recently captain in the U. S. Army and instructor in the engineers' school at Camp Humphreys, and formerly a member of the engineering faculties of Clarkson School of Technology at Potsdam, New York, and Rice Institute of Houston, Texas, has been appointed professor of civil engineering at George Washington University.

Mr. SAMUEL STOCKTON VOORHEES, engineer and chemist at the Bureau of Standards, died at Portland, Maine, on September 23, 1921, in his fifty-fifth year. Mr. Voorhees was born at Springfield, Ohio, January 15, 1867. During the first fifteen years of his professional work he was chemist or engineer of tests for several of the eastern railroad companies. From 1901 to 1908 he was with the supervising Architect's Office of the U. S. Treasury, and then went into chemical work at the U. S. Geological Survey. Since 1910 he had been in the chemical division of the Bureau of Standards, in charge of the chemical work on structural materials. He was a member of the ACADEMY, a past president of the Chemical Society, and a member of the Biological Society.